Northumbria University
NEWCASTLE

220-1

USAGE OF LANDMARKS IN VIRTUAL ENVIRONMENTS FOR WAYFINDING:

Research on the influence of global landmarks

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ABSTRACT

The role of global landmarks - those seen from multiple, distant points - and local landmarks - those viewed from a close distance - in virtual environment wayfinding has been discussed in a number of papers (Steck and Mallot, 2000; Hurlebaus *et al.*, 2008; Ruddle *et al.*, 2011). Some focused on the idea that local landmarks are more effective (Ruddle *et al.*, 2011); others mentioned that both global and local landmarks (Hurlebaus et al., 2008; Steck and Mallot, 2000) are influential on people's wayfinding performance. Recently, some studies focused on the importance of global landmarks and they suggested that global landmarks, as points of reference, are more useful in orientation in virtual environments (Lin et al., 2012). Thus, in this paper, we aim to better understand the effect of global landmarks on wayfinding. We used different virtual game-environments and compared two different conditions: the presence of local landmarks versus the presence of both global and local landmark conditions. Participants from all around the world (n=1.3 million) contributed to the study and were asked to view maps of environments first, then navigate a boat to find specific destinations that had been indicated on the maps. Environments were analyzed using axial and segment based integration, choice and intelligibility as well as visual connectivity and integration. In addition, segment lengths and the number of decision points in the map's layout were also analyzed. Levels with similar spatial values were chosen to compare the different landmark conditions. Preliminary findings indicate that global landmarks do not appear to have a significant impact on wayfinding. The large dataset underpinning this study contributes to our knowledge of the effect of landmarks by clarifying a gap in the literature - whether global and local landmarks or only one type of landmark are more influential on wayfinding.

KEYWORDS

Wayfinding, Local Landmarks, Global Landmarks, Virtual Environments.

1. INTRODUCTION

Landmarks are essential elements for wayfinding tasks (Ruddle et al., 1997; Von Stülpnagel and Steffens, 2013). Depending on their location during a wayfinding process, landmarks can be divided into two categories as global and local landmarks. Distant landmarks such as mountains and towers, which can be seen from a large area, are accepted as global landmarks (Steck and Mallot, 2000). Lynch (1960) describes global (distant) landmarks as elements seen from many angles and distances, and/or seen over the top of lower elements. In contrast to global landmarks, local landmarks are visible just from a small distance (Steck and Mallot, 2000); they are visible only in a limited area and only from certain approaches

(Lynch, 1960). Local landmarks can be trees, storefronts or innumerable signs (Lynch, 1960).

Lynch (1960) determined that people tend to use global landmarks only if they are unfamiliar with an environment. In his study (within a real environment), he observed that people used global landmarks only for very general orientation and they used local landmarks more frequently. In their study on environmental cognition, Evans and others (1984) focused on the effect of stress, landmarks and path configuration on environmental cognition. They discovered no significant differences between internal and external landmark conditions. However, they observed that there was a trend for internal landmarks to be more helpful than external ones. Lately, Ruddle and others (2011) hypothesized that adding both global and local landmarks in an environment would reduce the number of errors people make when they travel in virtual environments. They observed that although local landmarks did reduce participants' errors, global landmarks did not influence the overall number of errors. Therefore, contrary to their hypothesis, local and global landmarks interfered with each other and so they observed that participants who were provided both kinds of landmarks made more errors. Thus, in all these studies researchers observed that local landmarks were more effective on wayfinding. Similarly, Meilinger and others (2015) tested whether global landmarks improve spatial performance or not. For their study in a large-scale virtual environment, 33 participants were selected, and they were randomly assigned to three conditions: self-movement cues, self-movement and orientation cues and finally self-movement, orientation and distance cues. Results of this study showed that global landmarks did not have any dramatic influence on orientation. Researchers concluded the study by saying that proprioceptive information was sufficient to keep participants oriented. Moreover, in their previous study, Meilinger and his colleagues (2014) aimed to explain the effects of three factors: global reference frames, multiple local reference frames and orientation-free representations on representation in memory with two experiments. Participants of this study first completed the learning phase, and then they were asked to walk in an immersive virtual environment and point to seven learned targets. Results of this study also showed that participants relied on local reference frames rather than global reference frames or orientation free representations. They mentioned that survey tasks can be solved by the usage of interconnected local reference systems. Hence, these studies also pointed to the idea that global landmarks are not effective on wayfinding.

Schwering and others (2013), on the other hand, attempted to determine types of information that support orientation during wayfinding. Researchers discovered that in both tasks they organised (verbal instructions and sketch maps), participants provided both global and local information to help orientation. Furthermore, they suggested that including landmarks not only decision points but also along routes and off routes can make route orientation more efficient. In addition, in their study on virtual environments, Steck and Mallot (2000) hypothesized that people use different strategies; they may rely on only local landmarks, or global landmarks, or they may use some global and some local landmarks or they may use both kind of landmarks. They created visual environments to test their hypothesis and they discovered that some participants used only local landmarks for decisions when others used only global landmarks. In addition, they observed that some participants used local landmarks at one position and global landmarks at another. As a result of this study, they asked a new question: "how do participants select a landmark for a certain decision?" and they concluded the study by mentioning landmark saliency and by saying that functions of landmarks could also be effective on people`s preference. These studies gained importance to show that both landmark types can have an influence on wayfinding behaviours. Finally Schwering and others (2014) aimed to explore the use of landmarks in verbal descriptions for routes at different scales and different transportation modes. Findings of this study suggest that local landmarks are mostly used in the verbal descriptions whereas global landmarks are used for wayfinding and spatial orientation in new environments. They also discovered an increase in the usage of global landmarks (particularly regional global landmarks) for orientation as the distance increased. Results of this study was essential as it suggested that global landmarks might be more useful in new environments, which also supported Lynch's idea (1960) for how global landmarks are used in real environments. Other studies also pointed to the importance of the existence of both global and local landmark conditions (Anacta et al., 2014; Li et al., 2014).

Lin and others (2012) assessed gender differences in wayfinding in virtual environments. Researchers discovered that participants travelled longer paths in an environment with local landmark than in an environment with global landmarks. They explained this result by describing the 'anchor-point'[1] usage of global landmarks in orientation and the time that participants spent finding local landmarks. Hence, this study also gained importance by mentioning the importance of global landmarks within virtual environments.

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[1] "Anchor-points (anchors for short) are closely related to landmarks, both concepts being defined as cognitively salient cues in the environment. However, as represented in the literature, landmarks tend to be collectively as well as individually experienced as such, whereas anchors refer to individual cognitive maps. Although one would expect to find several local landmarks among the anchors in a person's cognitive map, many anchors (such as the location of home and work) would be too personal to have any significance for other, unrelated individuals. Further, landmarks are primarily treated as part of a person's factual knowledge of space, whereas anchor-points are supposed to perform in addition active cognitive functions, such as helping organize spatial knowledge, facilitating navigational tasks, helping estimate distances and directions, etc. Finally, landmarks are concrete, visual cues, whereas anchor-points may be more abstract elements that need not even be point-like" (Couclelis et al., 1987 Page 102).

Based on the different results within the literature, this study aims to explore the effect of location of landmarks on wayfinding performance. By using a large dataset, we aim to have accurate results on the impact of global and local landmarks on wayfinding performance. Our hypothesis is that, in environments with global landmarks the time taken to complete the levels will decrease as participants will use the global landmarks as environmental clues.

2. METHODS

To test the influences of landmarks on wayfinding a game produced by an independent games design company, Glitchers Ltd. (Hyde et al., 2016), for smart phones and tablets is used. The game "Sea Hero Quest" (SHQ) (Coutrot et al., 2018) was released in 2016 and 3,7 million participants completed at least the first level of the game.

Wayfinding in the game environments (for layouts of some levels see Figure 1) is controlled by three moves; tap right to turn right, tap left to turn left and swipe up (boost) to accelerate. There are 75 levels and mainly three kinds of tasks required to complete the game. In the *wayfinding levels* (44 levels), which are used in this study, participants first are asked to look at a map that includes their current location and goal locations they should reach. Then the map disappears, and they are asked to navigate a boat in a virtual environment and look for the goal locations. In order to play next levels, participants are first asked to complete the previous levels.

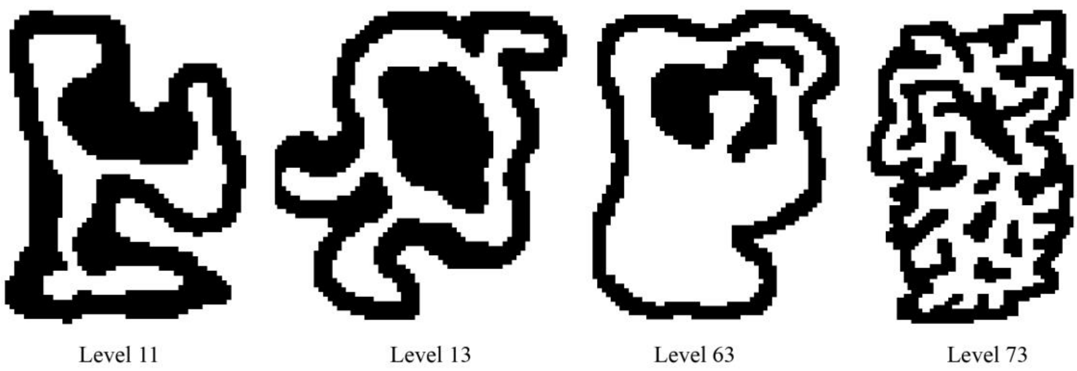

Figure 1: Layouts of the selected game levels (Source: Glitchers Ltd. (Hyde et al., 2016))

The first wayfinding level, which was also the first level of the game, was excluded from the analysis because this level was designed as a training phase. The data which is used in this study includes results of 1.3 million people (for the second level) who volunteered information about their age and gender (participants aged between 18-99; 769,556 male, 551,295 female and 326 other).

In order to explain the effect of landmarks first the spatial structure of levels was compared and then the levels which include similar theme (different environments were created in the game, only two of them were used in this paper: Arctic Rivers and High Rollers), type (three different tasks, only checkpoint levels were selected), weather conditions, variety of landmarks and existence of global landmarks were grouped. In order to analyse the spatial characteristics of levels, average values of axial and segment-based[2] choice (radius r: n, 3), visual integration and choice as well as average axial intelligibility, segment length, number of decision points and number of destinations of levels were measured in Depthmap X 0.50. Results of the levels were clustered in statistical software JMP with hierarchical clustering method (Figure 2). As it can be seen in figure 2, 5 clusters were automatically produced, represented with different colours and shapes.

2.1. Selection of levels

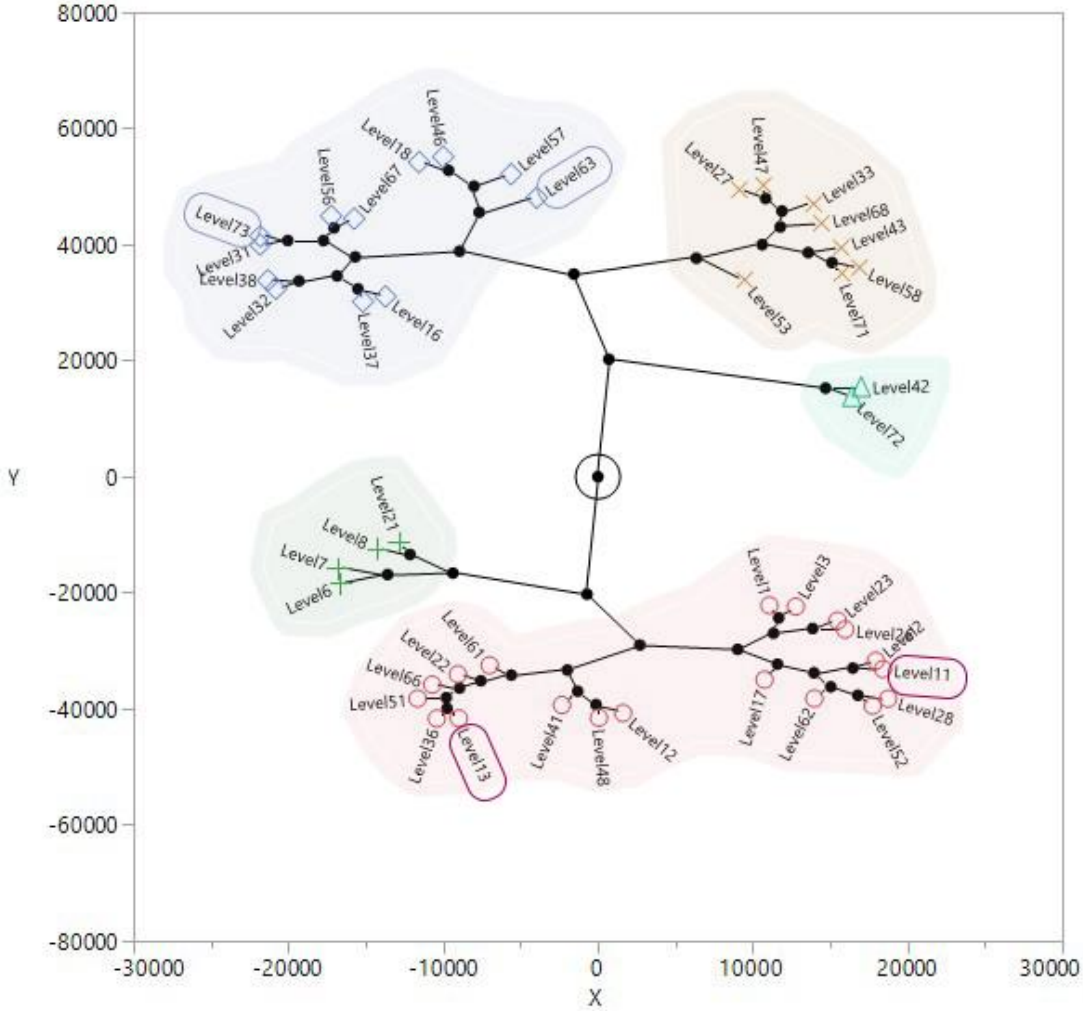

Figure 2: Constellation plot of all levels through the use of all measures

[2] In order to produce segment maps, first the edges of the moveable spaces were represented with points, and then Voronoi polygons were created in ArcMap 10.3. Segment lines were drawn from the intersections of Voronoi polygons.

As a second step of the analysis, conditions of levels were compared. Table 1 demonstrates different theme, type, landmark (categorised based on the saliency of landmarks and accessibility of their positions), existence of global landmarks and weather conditions of 4 selected levels. Levels 11 and 13 as well as level 63 and 73, which are located in the same clusters, were analysed separately based on the time taken by participants. Care was taken to ensure that all attributes, apart from the presence of global landmarks, were matched.

Table 1. Attributes of the selected levels

Level	Theme	Type	Landmarks	Global	Weather
11	Arctic Rivers	Checkpoint	Easy	Yes	Clear
13	Arctic Rivers	Checkpoint	Easy	No	Clear
63	High Rollers	Checkpoint	Hard	No	Waves
73	High Rollers	Checkpoint	Hard	Yes	Waves

2.2. Participants

To make a comparison between these two-binary groups only the players who played both levels were used. Before this step, outliers[3] (based on the logarithm of the duration of the levels) in the dataset detected and excluded. For levels 11 and 13, the total number of results collected was 1,666,438 with 52,206 outliers. And for levels 63 and 73 it was 41,813 with 2,091 outliers. After the outliers were detected and excluded, the participants who played two levels (level 11 and 13 or level 63 and 73) were analysed to compare the results fairly. The number of participants who played both levels 11 and 13 was 706,180 (201,872 results belonged to only one level were excluded) and number of participants who played both levels 63 and 73 was 28,414 (11,308 results were excluded).

3. RESULTS

Before comparing the time taken by participants to complete a level, the shortest realistic routes of the environments were measured in order to consider the effect of the spatial layout and its effect on wayfinding (Carlson et al., 2010). Segment maps were used to measure the shortest realistic route and all goal locations were tracked respectively. Once the shortest realistic routes were measured for all levels, maximum (usage of the speed up command during the game) and minimum (without boost) speed of the boat was used to measure the seconds that would be spent to complete a level and logarithmic transformation was applied

[3] Outlier formula: Upper value=upper quartile + (1.5 * (inter quartile range, IQR))
Lower value= lower quartile - (1.5 * (inter quartile range, IQR))

to the results (Table 2, heading A and B) in order to have a normal distribution. Real time spent by participants during the game was also measured and mean durations were calculated (Table 2, heading E). By using just the real time duration that was spent by participants, it is first clear that duration increases as the levels change. Between levels 11 and 13, a slight increase in mean duration can be seen. Likewise, mean duration of level 73 is also higher than level 63. This makes sense as the levels are intended to become progressively more difficult the longer the player plays the game. However, when the ratio of mean duration and expected duration is calculated, the results change. Table 2 shows the ratio of real duration to expected duration with boost, meaning assuming the maximum accelerated speed, (C) and without boost (D). In both conditions, with acceleration, or without it, it took more time for participants to complete level 11 than level 13. Similarly, it is also observed that it took more time for the participants to complete level 73 than level 63. When these results are compared to the attributes of the levels, it can be seen that both levels 11 and 73, where the environments include global landmarks, duration increased slightly. Hence, it can be stated that it took more time for participants to complete the levels where there were global landmarks (all other things being equal).

Table 2: Comparison between real and expected duration

Levels	(A)Duration with boost	(B)Duration without boost	(C)Ratio _reald_ b	(D)Ratio_reald_wb	(E)Real Duration (mean)
11	1.561	1.769	1.150	1.015	1.796
13	1.632	1.839	1.125	0.998	1.835
63	1.680	1.888	1.221	1.087	2.052
73	1.737	1.944	1.403	1.253	2.437

Thus, as a result of this study, it can be argued that no significant, or even an inverse, effect of global landmarks was observed on wayfinding.

4. CONCLUSIONS

The primary objective of this study was to investigate whether global and local landmarks or only one type of landmark is more influential on wayfinding performance of people. To achieve this goal, we used forty-four different levels of SHQ and clustered levels based on their syntactical values. Four different virtual environments from the original set of forty-four were selected to compare, controlling for all other attributes of the levels. Then these levels were investigated based on the time participants spent to complete the levels and the ratio between the real duration (which was taken by participants) and expected duration (that was calculated based on the shortest realistic routes). The results of the analyses showed that there was no significant decrease in completion duration when the environment contained global landmarks. The results of this study support some other studies in the literature which also did not observe any significant influence of the global landmarks on wayfinding performance (Ruddle et al., 2011). Moreover, in levels containing global landmarks, it took more time for participants to complete the tasks. On further scrutiny of the environments (both levels 13 and 63 which did not have any global landmarks), it was observed that these environments had a ringy layout. Thus, it was concluded that in these levels the layout might make it easier for participants to recover from wrong wayfinding decisions made. As mentioned in earlier studies (Carlson et al., 2010), this paper also concluded by saying that the layout of environments are vital to the movement of people and cannot be fully separated from the presence of landmarks: there is always an interaction between the two.

The present study is essential as it consists of the largest dataset in landmark and wayfinding studies in virtual environments generated to date. The total number of participants was 1.3 million and the number of participants whose results were compared in this study was 706,180 (for levels 11 and 13) and 28,414 (for levels 63 and 73) that makes this study an important contribution to the debate on the effect of landmarks, in terms of the potential accuracy of the results.

On the other hand, in this paper only two conditions – the existence of both global and local landmarks and the existence of only local landmarks - were compared. A no-landmark condition was not included in this study because of the hierarchical clustering. Even though there were levels where there were similar conditions (weather, difficulty and type) and various landmark conditions (existince of no landmarks, only local landmarks, and both global and local landmarks), these levels were not used in this study due to the fact that they located in different clusters.

Another limitation of this study is that classification of whether a landmark was global or local, that were compared in this study, were pre-defined by the designers of the game-levels (Dalton, Hölscher and Wiener- see Dalton, 2016). A further study will aim to identify global and local landmarks for specific levels in order to have a more accurate rating. Finally, logarithmic duration was used in this study to have normal-distributed data. However, in navagational performance it is possible to have long tails. Thus, for future research it is also aimed to use the real duration instead of logarithmic duration.

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